Molecular dynamics studies from heavy-ion collisions to neutron stars

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The nuclear equation of state is an important ingredient in the process of supernova explosion, and proto-neutron star formation and cooling. Especially, the density inhomogeneity at the sub-saturation density induced by the nuclear liquid-gas phase transition may have significant effects on these physics [1, 2, 3, 4]. Indeed the density inhomogeneity of nuclear matter reduces the opacity of neutrino so that it helps the neutrino heating process. The presence of clustering modifies the temperature dependence of the symmetry energy respect to homogeneous mean-field estimations, which in turn has an important effect on the energy density implied in the explosion.

One of the possible probes of the nuclear equation of state on the earth is the study of heavy-ion collisions. It is done usually by comparing the experimetal results with the theoritical predictions of transport models adopting various type of effective interactions. In medium energy ($30 \sim 100$ MeV/nucleon) heavy-ion collisions, the multifragmentation, namely the copious production of intermediate mass fragments as well as a large number of light particles, is observed. The multifragmentation is considered to have some connection to the nuclear liquid-gas phase transition.

We try to establish a framework which is able to study these two situations, namely the sub-saturation density star matter and the process of medium energy heavy-ion collisions in a unified way. They are governed by the nuclear equation of state in approximately same region and the existence of the density inhomogneity induced by the nuclear liquid-gas phase transition are essential in both situations. We utilize antisymmetrized molecular dynamcs (AMD), which is a microscopic dynamical model based on the nucleonic degrees of freedom. AMD has been utilized to study heavy-ion collisions and successfully reproduced many aspects of experimental data of heavy-ion collisions including the multifragmentation reactions [5]. In order to apply AMD to the study of the sub-saturation star matter, we need to introduce some extensions to the model, for instance, the inclusion of the electron effects and the bondary condition in order to treat inifinite matter. Numerical improvements are also necessary since we have to treat the system with large number of nucleons (more than 1000 nucleons). In this presentation, I will present these developments and discuss the possibility of the actual calculations for the sub-saturation star matter with our model.

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